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Quality Assessment of Formulated Osmotically Dehydrated Cashew Apple (*Anacardium occidentale* L.) Slices Dried using Hot air and Solar Driers

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Key words: Cashew apple, Osmotic dehydration, Solar drying, Hot air drying, Value addition.

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Abstract

Cashew apples are rich in phytochemicals particularly vitamin C and yet are highly underutilized in low technological countries. This study investigated the effect of drying methods on quality attributes of osmotically dehydrated cashew apples. Specifically; nutrient retention, rehydration coefficient, microbial safety and sensory attributes were assessed. Fully matured, ripe and intact fruits were washed, blanched, sliced, and immersed in 70% sucrose before drying on hot air and solar drier. No significant difference ($p > 0.05$) was observed on carotenoids (0.28-0.33 g/100g), vitamin C (0.73-0.85 g/100g), and tannins (266.59-267.95 mg/100g) in both dried cashew apple slices, except on significantly higher total phenolic ($p < 0.05$) in hot air-dried slices. During storage at room temperature for 60 days: total phenolic, tannins, and vitamin C were significantly reduced ($p < 0.05$) in both hot air and solar dried slices; while carotenoids were maintained ($p > 0.05$) in hot air-dried slices, and slightly reduced ($p < 0.05$) in solar dried slices. Solar dried slices had better rehydration efficiency compared to hot air-dried ones. Both dried products had similar ($p > 0.05$) overall acceptability, and zero microbial counts when observed for 60 days. Though solar drying retained less of the desirable nutritive values, it is relatively cheaper and is recommended for use in low resource settings.

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Introduction

Cashew (*Anacardium occidentale* L.) apple is an accessory fruit native in Brazil. The fruit is rich in nutrients and phytochemicals including vitamin C, sugars, carotenoids, minerals, dietary fibres, and polyphenols (Adou *et al.*, 2012; Msoka *et al.*, 2017). For instance, it contains about five times vitamin C content compared to tropical fruits including mango, pineapple and orange (Akinwale, 2000). Due to its pronounced nutritional importance, various value-added products such as juice, jam, marmalades, and wine could be obtained from cashew apple (Runjala and Kella, 2017). Despite the potential of the cashew apple, there is a nearly total postharvest loss particularly in Africa (Yantannou, 2017) due to high perishability, lack of processing technologies, short harvesting period, and astringency that hinder the utilization (Bidaisee and Badrie, 2001).

Several postharvest technologies for cashew apples have been documented to maintain the quality, prolong shelf life, and ultimately reduce the postharvest losses (Das and Arora, 2016). Osmotic dehydration is one of the low-temperature preservation technique in which the solid food is immersed in a concentrated solution for a specified period during which, water comes out of the fruit while the solute moves in the opposite direction. Besides, leaching out of fruits own solutes such as vitamins, minerals and organic acids occurs (Yadav and Singh, 2014; Ramya and Jain, 2016). However, osmotic dehydration retains many nutrients and organoleptic attributes, hence impart desirable characteristics to the finished products (Yadav and Singh, 2014; Mini and Archana, 2016; Kaushalya and Weerasooriya, 2017). Factors such as temperature, osmotic agents and concentration, and immersion time influence mass transfer indices during the osmotic process (Ramya and Jain, 2016).

Osmotic pretreatment has proven to be effective in many other fruits such as guava fruit (Kushwaha *et al.*, 2018), papaya (Jain *et al.*, 2011), banana (Ali *et al.*, 2010), mulberry fruit (Ojha *et al.*, 2017), and cranberry (Beaudry *et al.*, 2007).

In Tanzania, cashew farming has been focusing on nut production which is considered an important cash crop over the apple. For instance in the year 2015, cashew nut export contributed about 497.4 billion Tanzanian Shillings to the national economy which is equivalent to 10.97% (Msoka *et al.*, 2017), while nearly a negligible proportion of the highly perishable apples are eaten fresh or locally processed, and the largest percentage left to rot in the field. Moreover, the small proportion of cashew apples processed into traditional products such as cashew apple porridge and alcoholic beverages are neither standardized nor commercialized in the market (Dimoso *et al.*, 2020). These denote a considerable under-utilization of cashew apples in the country, with the lack of processing technologies and skills being the main contributing factors. Therefore, this paper assessed the effect of hot air oven and solar drying enhanced by osmotic dehydration on nutritional, rehydration efficiency, microbial safety and sensory attributes of dried cashew apple slices.

Material and methods

Sample collection and preparation

Red Brazilian Dwarf cashew apples were obtained from the orchards owned by Tanzania Agricultural Research Institute (TARI) in Nachingwea district (10°19′46″S, 38°46′46″E; 442 metres above sea level). This variety was chosen because of high nutrients and low tannin contents (Msoka *et al.*, 2017). Full matured ripe and intact fruits were hand-plucked from the tree, kept in a cool box and transported to the laboratory within 20 hours for further preparation before processing.

The average initial pH and total soluble solid of the fruits were 3.6 ± 0.3 and 13.3 ± 0.2 °Brix respectively. The values of pH and total soluble solid are good indicators of the ripeness of the fruit, with the range of pH from 3.5 to 4.6 and soluble solid from 9.8 to 14.0 °Brix be considered fully matured and ripe (Silva, 1998). The fruits were sorted and washed with tap water to reduce microbial load and soil debris, and then wrapped in polyethylene films before storage at -20 °C before processing.

Osmotic dehydration of cashew apple slices

Before osmotic treatment, cashew apples were thawed by dipping in nano-filtered water at room temperature and nut removed. The fruits were hot-water blanched at 90 °C for 5 minutes in a thermostatic water bath to reduce astringency. Then they were transversely sliced manually into ~10 mm thickness using a sharp stainless steel knife, weighed and then immersed into 70%, wt/wt sucrose syrups in a 1 L beaker for 24 hours at 27-29 °C. The fruit sample to syrup ratio used was 1:4 (wt/wt). After 24 hours, sliced cashew apples were immediately removed from the solution, drained, rinsed with potable water and placed on absorbent paper to remove surface moisture.

Drying of osmotically dehydrated cashew apple slices

Following the osmotic treatment, samples were further dried to reduce the moisture content to about 15% by using a natural convention hot air oven at 60 °C for 48 hours, or natural convection mixed solar drier for 5 ± 1 days. The temperature inside the solar drying chamber ranged from 31 ± 1.11 °C for the down hours to 62.12 ± 0.63 °C for the pick hours, making an average drying temperature of 47.53 ± 1.09 °C. After sunset, the products were removed from the solar drier to avoid regaining moisture from the surrounding. The dried samples were allowed to cool, then packaged in low-density polyethylene laminated aluminum pouches and stored at room temperature (26 ± 1 °C). Dried samples were analysed for shelf-life stability at a time frame of 0, 30 and 60 days on the following parameters; pH, moisture content, total acidity, total ascorbic acid, total phenolic contents, tannin contents, carotenoid contents, rehydration efficiencies, and microbial quality.

Physiochemical analysis of fruit samples

Determination of moisture content, total titratable acidity (TTA), and pH

Moisture content (%), TTA (% citric acid), and pH of fruit sample were determined as described by Bidaisee and Badrie, (2001) with some modifications. Briefly, moisture content was obtained by drying fruit samples for 24 hours in an oven at 105 °C. The pH of the sample was determined by homogenizing 20 g of well-pulped fruit sample in 100 mL distilled water and allowed to stand for 30 minutes. The filtrate was collected and centrifuged (Eppendorf Centrifuge 5810, Germany) at 3000 rpm for 10 minutes. The pH of the supernatant was measured on a digital pH meter (GHM 3531, Germany). The TTA of the fruit sample extract (as prepared for pH) was determined by placing 25 mL of extract in a beaker placed on a magnetic stirrer of a digital titration burette (TITRONIC Basic module 2, Germany) and titrated against 0.1 mEq/mL NaOH solution until the endpoint at pH 8.2 and calculated based on the formulae by Sadler and Murphy, (2010).

$$\%\ acid\ (wt/wt) = \frac{0.1\ mEq/mL\ NaOH\ X\ volume\ NaOH\ (mL)\ X\ 64\ mg/mEq}{weight\ of\ sample\ (g)\ X\ 1000} x100$$

Where, 64 mg/mEq = Equivalent weight of citric acid, and 1000 is a factor relating mg to grams (mg/g) (1/10 = 100/1000).

Determination of carotenoid contents

Carotenoid content (g/100g dry basis) of fruit sample was extracted and determined as described by Perez-lopez, (2010) and AOAC (1980) with little modification. Five grams of well-pulped sample was placed into a 50 mL falcon tube. Then 40 mL of extraction solvent; hexane: acetone: ethanol (2:1:1) was added and the mixture was centrifuged at 4000 rpm for 5 minutes. The residue was re-extracted until it became colorless. The mixture was transferred into a separating funnel and 50 mL of 10% sodium chloride was added to remove residual acetone. The upper phase was recovered, dried over anhydrous sodium sulphate and determine its absorbance at 450 nm (UV/Vis spectrophotometer) and concentration based on the standard curve of β-carotene.

Determination of total ascorbic acid content (TAA)

Sample and reagent preparation and subsequent determination of TAA were conducted as described by Kapur *et al.* (2012). Briefly, 5 g of fruit sample was mixed with 25 mL of 3% metaphosphoric acid – 8% acetic acid solution and centrifuged at 4000 rpm for

15 minutes. Exactly 4 mL of the extract was treated with 0.23 mL of bromine water, 0.13 mL of 10% thiourea solution, and 1 mL of 2, 4-dinitrophenylhydrazine solution. The mixture was kept in a thermostatic water bath at 37 °C for 3 hours, cooled in an ice bath for 30 minutes and then treated with 6 mL chilled 85% sulphuric acid, with constant stirring. The absorbance of the resulted red coloured solution was measured at 521 nm. The TAA (mg/100g dry basis) was estimated based on the standard curve of ascorbic acid.

Determination of total phenolic content (TPC) and Tannins content

Sample assay solution was prepared as described by Ojha *et al.* (2017), and determine TPC (mg/100g Gallic acid equivalent) using Folin-Ciocalteu method as described by Mahdavi *et al.* (2011). Pulped fruit sample (10 g) was mixed with 30 mL of 80% methanol and centrifuged at 3000 rpm for 15 minutes. The residue was re-extracted twice. Exactly 1 mL of the methanol extract was diluted ten times with extraction solvent. An aliquot (0.5 mL) of the diluted sample was mixed with 2.4 mL of deionized water, 2 mL sodium carbonate (2%), and 0.1 mL of Folin-Ciocalteu reagent. The mixture was incubated in a dark place at room temperature for 60 minutes and read absorbance at 750 nm. To determine non-tannin phenolic content (NTPC), 2 mL of the diluted sample was mixed with 100 mg polyvinyl-polypirrolidone (PVPP). The mixture was vortexed, left for 15 minutes at 4 °C and centrifuged at 3000 rpm for 10 minutes. The NTPC in the supernatant was determined as described for TPC. Tannin content was estimated as the difference between TPC and NTPC in the fruit samples.

Rehydration efficiency of dried cashew apple products

The fruit products (10 g) were rehydrated by immersing in boiling water contained in a beaker which was placed on a magnetic stirrer with a heater (MR Hel-Standard, Germany) for 20 minutes at a ratio of 1:10 (wt. product: wt. water). The products were removed, drained, and allowed to cool at room temperature. Rehydration ratio (RR), rehydration coefficient (RC), and percent water content were computed according to formulae by Srivastava and Kumar, (2012).

$$RR = \frac{\text{drained weight of rehydrated sample, g}}{\text{weight of dehydrated sample taken for rehydration test, g}}$$

$$RC = \frac{\text{drained wt. of rehydrated sample} - \text{dry matter of sample for rehydration}}{\text{drained weight of rehydrated sample}} x100$$

Microbial analysis of dried cashew apple slices

Bacterial and fungal counts were analysed separately by pour plate technique as described by Kaushalya and Weerasooriya, (2017) with little modification. Briefly, 1 g of dried cashew apple slices was mixed with 9 mL of sterile peptone salt and vortexed for 5 min. Then, 1 mL of the suspension was transferred into the peptone salt diluents (9 mL) up to 10^{-3} of dilution series. From each dilution, 1 mL of diluted sample was inoculated into the respective growth medium: Plate count agar (PCA) for bacteria and potato dextrose agar (PDA) for yeast and mold. The incubation conditions were 1 day at 30 °C for bacteria and 3 days at 30 °C for yeast and mold.

Sensory evaluation of dried cashew apple slices

The organoleptic characteristics of the fruit products were evaluated using a 5-point hedonic scale concerning attributes of taste, colour, aroma, texture, astringent, and overall acceptability. The scale except for astringency, ranged from 1 'dislike very much' to 5 'like very much' as described by Watts *et al.* (1989), cited by Bidaisee and Badrie, (2001). The scores for astringency were ranged from 5 'no astringent' to 1 'extremely astringent' (Mohammed and Wickham, 1994). Two hundred untrained panelists were used to evaluate the samples in a well-designed booth with the appropriate condition of wind, sound, fragrance, and light. Samples were given to the panelists in a randomized order. Samples were labeled alphabetically: A = Solar dried sample; B = Hot air-dried sample; C = Hot air-dried sample without osmotic treatment as a control.

Statistical analysis

Data were analysed by one-way analysis of variance

(ANOVA), except for rehydration efficiency where an independent t-test was applied with the aid of a statistical package (SPSS). All measurements were done in triplicate and expressed as mean value ± standard error of the mean (SEM). The Duncan's Multiple Range Test was applied to evaluate the significant differences of the mean values at $p < 0.05$.

Results and discussion

Physicochemical properties of fresh and dried cashew apples

The physicochemical parameters of fresh cashew apples, mixed solar dried, and hot air oven-dried fruit slices were compared (Table 1). The moisture content of the dried samples was maintained below 16% on a dry basis to inhibit the growth of spoilage microorganism's hence prolonged shelf life of the product. According to the CODEX General Standard (CODEX STAN 130-1981), the maximum permissible moisture content for osmotically dehydrated fruits is 20% on a dry basis. Both dried fruit products had significantly ($p < 0.05$) lower total acidity and higher pH values than fresh fruit. This could be due to the leaching of organic acids during osmotic dehydration (Yadav and Singh, 2014; Ramya and Jain, 2016). Furthermore, the reduction of organic acids and uptake of sugars during osmotic treatment resulted in sweeter products compared to conventionally dried products (Yadav and Singh, 2014).

Table 1. Physicochemical parameters of fresh and dried cashew apples slices.

Parameters	Fresh fruit	Hot air oven dried slices	Solar dried slices
Moisture content (%)	81.31±0.18 ^{b}	15.02±0.66 ^{a}	13.81±0.28 ^{a}
pH	3.80±0.01 ^{a}	4.31±0.05 ^{b}	4.55±0.03 ^{c}
Total titratable acidity (%)	0.32±0.01 ^{b}	0.20±0.01 ^{a}	0.19±0.01 ^{a}
Carotenoids (g/100g dry basis)	1.33±0.02 ^{b}	0.33±0.03 ^{a}	0.28±0.01 ^{a}
TPC (mg/100g GAE dry basis)	815.32±9.59 ^{c}	671.26±29.97 ^{b}	542.75±6.15 ^{a}
Tannins (mg/100g GAE dry basis)	388.96±7.37 ^{b}	267.95±18.06 ^{a}	266.59±1.89 ^{a}
Total ascorbic acid (g/100g dry basis)	1.95±0.09 ^{b}	0.85±0.01 ^{a}	0.73±0.01 ^{a}

Means with similar letter in the same row are not significantly different from each other ($p > 0.05$). TPC: Total phenolic content; GAE: Gallic acid equivalent.

Ascorbic acid is the principal nutritional compound in cashew apple. The edible portion is reported to contain about four times the amount of ascorbic acid as compared to other tropical fruits including mango, orange, and pineapple (Akinwale, 2000; Msoka *et al.*, 2017). The dried products had significantly ($p < 0.05$) lower ascorbic acid content than in the fresh fruit (Table 1). The loss of ascorbic acid could be due to leaching during osmotic dehydration (Ramya and Jain, 2016), oxidation at a higher temperature (Reis *et al.*, 2013), and to a lesser extent during blanching (Lagnika *et al.*, 2019). The lower ascorbic acid content of solar-dried samples could be attributed to the longer drying time, exposure to sunlight, and higher temperature inside the drier. The retained amount of ascorbic acid (850 mg/100g and 730 mg/100g for hot air and solar dried samples respectively) is still higher compared to fresh fruits such as strawberry, lemon, orange and grapefruit reported by Szeto *et al.* (2002). The retained amount of ascorbic acid in both dried products suggests that the products could still save as a good source of ascorbic acid.

Cashew apples contain a significant amount of phenolic compounds such as flavonoids and phenolic acids (Adou *et al.*, 2012). Polyphenols possess antioxidant and anti-inflammatory activities, hence important in the prevention and treatment of chronic diseases such as cancer and cardiovascular diseases (Zhang *et al.*, 2015). The total phenolic content of dried cashew apples was significantly ($p < 0.05$) lower than in fresh fruit (Table 1). Leaching during osmotic dehydration and hot water blanching, and thermal degradation during blanching could be responsible for the decrease in total phenolic contents as reported previously (Larrauri *et al.*, 1997; Bamidele *et al.*, 2017; Lagnika *et al.*, 2019). Solar dried cashew apple slices had significantly lower ($p < 0.05$) total phenolic content compared to hot air oven-dried samples. This could be due to higher temperatures inside the drier. Larrauri *et al.* (1997) reported a significant loss of total phenolic content and anthocyanin in red grape pomace peels dried at over 60 °C. Similar to red grapes, anthocyanin is also found in red cashew apples. After blanching red cashew apples turned yellow, indicating the loss of anthocyanin.

Table 2. Rehydration efficiency of dried cashew apple products.

Fruit products	Rehydration ratio	Rehydration coefficient	Percent water
Solar dried products	1.39±0.01	0.38±0.03	71.94±0.32
Hot air oven dried products	1.21±0.02	0.29±0.01	69.68±0.55

The astringent property of cashew apples is attributed mainly to tannins which are intentionally reduced to improve product acceptability. Blanching in hot water or steam is reported to reduce tannin content in cashew apples (Bidaisee and Badrie, 2001; Emelike and Ebere, 2016). Tannins are mainly found in the waxy layer of cashew apple skin, with the hydrolysable tannins present in higher concentration than condensed tannins (Ortiz *et al.*, 1982; Emelike and Ebere, 2016). In this study, tannin contents in dried products are significantly reduced ($p < 0.05$) compared to that of fresh fruit (Table 1) owing mainly due to hot water blanching. Carotenoid contents varied between dried products and fresh fruit (Table 1). Dried cashew apple slices had a significantly lower ($p < 0.05$) amount of carotenoids compared to fresh fruit. Though solar-dried samples presented the lowest carotenoid content than hot air oven-dried samples, the difference was not significant ($p > 0.05$). The loss of carotenoids could be due to blanching and higher drying temperature. Carotenoids are reported to be more sensitive to drying temperature than drying time. According to Mohamed and Hussein (1994), carotenoids were highly retained for samples dried at 40 °C for a longer time than above 40 °C for a shorter time. The values of the carotenoid content of dried products were similar to those reported by Mini and Archana (2016).

Table 3. Quality parameters of dried apple slices during storage at room temperature.

	Hot air oven dried products			Solar dried products		
	0 days	30 days	60 days	0 days	30 days	60 days
MC	15.02±0.66 ^{c}	10.19±0.18 ^{b}	8.37±0.03 ^{a}	13.81±0.28 ^{c}	9.95±0.14 ^{b}	8.05±0.15 ^{a}
pH	4.31±0.05 ^{a}	5.67±0.03 ^{b}	5.77±0.03 ^{c}	4.55±0.03 ^{a}	5.68±0.02 ^{b}	5.81±0.02 ^{c}
TTA	0.20±0.01 ^{b}	0.16±0.01 ^{a}	0.15±0.01 ^{a}	0.19±0.01 ^{c}	0.16±0.01 ^{b}	0.14±0.01 ^{a}
CC	0.33±0.03 ^{a}	0.31±0.01 ^{a}	0.30±0.01 ^{a}	0.28±0.09 ^{b}	0.24±0.01 ^{a}	0.23±0.01 ^{a}
TPC	671.26±29.97 ^{c}	519.34±2.03 ^{b}	360.84±1.58 ^{a}	542.75±10.66 ^{c}	412.00±3.94 ^{b}	274.44±4.85 ^{a}
TC	267.95±18.06 ^{b}	241.41±1.36 ^{b}	158.19±1.31 ^{a}	266.59±1.89 ^{c}	223±14±3.17 ^{b}	160.12±5.48 ^{a}
TAA	0.85±0.01 ^{b}	0.84±0.01 ^{ab}	0.83±0.01 ^{a}	0.74±0.01 ^{c}	0.70±0.01 ^{b}	0.60±0.01 ^{a}

Means with similar letter in the same row and within the same column *i.e.* Column for hot air oven dried products, and column for solar dried products are not statistically different from each other ($p > 0.05$). TTA: Total titratable acidity (%); MC: Moisture content (%); TPC: Total phenolic content (mg/100g GAE dry basis); TC: Tannin content (mg/100g GAE dry basis); GAE: Gallic acid equivalent; TAA: Total ascorbic acid (g/100g dry basis); CC: Carotenoid content (g/100g dry basis).

Rehydration efficiency of dried cashew apples

The rehydration capacity of dried products could be used as a quality indicator that determines the ability of the products to acquire moisture when in contact. Pre-treatments and drying conditions influence many changes in plant material subjected to rehydration (Lewicki, 1998). When the internal structure of the fruit remains undisturbed during drying, the collapse of the fruit solid matrix is prevented after drying. The resulting product will have large voids or porous structure, and no shrinkage hence an increase in rehydration efficiency (Lewicki and Pawlak, 2007). Solar dried products had higher values of rehydration ratio, rehydration coefficient, and percent water content than hot air oven-dried products (Table 2). This could be attributed to the porosity of solar-dried samples due to good air movement inside the drier. Ultrasound as pretreatment and freeze-drying of fruits improve the rehydration of dried products than blanching and drying methods such as hot air drying, microwave, and vacuum drying (Beaudry *et al.*, 2004; Ricce *et al.*, 2016; Lagnika *et al.*, 2019).

Stability of dried cashew apple slices during storage at room temperature

Storage stability of dehydrated cashew apple slices was investigated for 60 days (Table 3). In addition to nutrient loss during blanching, osmotic dehydration, and drying, a significant loss occurred during storage. This loss could be attributed to packaging material, pH, storage temperature, exposure to light and oxygen, and organic acids present (Sablan, 2006). In the present study, the moisture content of dried products declined significantly ($p < 0.05$) with the increase in storage days (Table 3). This could be due to continuous evaporation occurred during storage. Similar trends have also been reported by Kushwaha *et al.* (2018) on osmotically dehydrated guava fruit. It is noteworthy that, the loss of moisture in dehydrated products could be reduced by efficient packaging strategies such as vacuum packaging, barrier packaging, and active packaging (Yildirim *et al.*, 2018). Furthermore, the use of active packaging such as desiccants (sodium chloride, bentonite, sorbitol, etc) is considered a novel strategy for maintaining moisture content and it has been successfully applied in the storage of mushrooms, strawberries and tomatoes (Mahajan *et al.*, 2008; Rux *et al.*, 2016). Though remarkably efficient, they are quite expensive and unavailable in low resource settings.

Table 4. Sensory evaluation scores of dried cashew apple products.

Sample	Color [A]	Texture [A]	Taste [A]	Aroma [A]	Astringent [B]	Overall acceptability [A]
A	4.91 [a]	4.86 [b]	4.92 [a]	4.94 [a]	4.90 [a]	4.87 [a]
B	4.96 [a]	4.93 [a]	4.95 [a]	4.95 [a]	4.96 [a]	4.93 [a]
C	3.54 [b]	3.18 [c]	2.81 [b]	3.25 [b]	2.77 [b]	3.07 [b]

Means with same letters in the same column are not significantly different ($p > 0.05$). A: Solar dried sample; B: Hot air oven dried sample; C: Hot air dried sample without osmotic treatment. [A] Mean values based on 5-point Hedonic scale (5 = like very much; 1 = dislike very much); [B] Mean values on 5-point scale (5 = no astringent; 1 = extremely astringent).

Total titratable acidity of dried products decreased significantly while pH values increase significantly during storage (Table 3). A study by Mini and Archana, (2016) showed a similar trend on the reduction of total acidity of dehydrated cashew apple in 6 months, while Kushwaha *et al.* (2018) observed an increase of total acidity of dehydrated guava during 45 days of storage. According to Sablan, (2006), the nature of food material itself plays a significant role in nutrient retention. Both cashew apple slices dried by hot air oven and solar drier showed the same pattern of changes in pH and total acidity during storage. Total ascorbic acid of dried products was observed to change during storage (Table 3). Hot air oven-dried samples showed no significant difference ($p > 0.05$) in ascorbic acid after 30 days of storage, and between 30 to 60 days of storage. However, the total ascorbic acid decreased significantly ($p < 0.05$) from day 0 to day 60 during storage. For solar-dried samples, a significant decrease ($p < 0.05$) of total ascorbic acid after 30 days and 60 days of storage was observed.

The observed loss could be due to water solubility and oxidation of ascorbic acid to furfural compounds (El-Gharably *et al.*, 2014). A similar reduction of total ascorbic acid during storage has been reported in osmotically dehydrated cashew apples (Mini and Archana, 2016) and osmotically dehydrated guava (Kushwaha *et al.*, 2018). Hot air oven-dried samples showed no significant difference ($p > 0.05$) in carotenoid content during 60 days of storage (Table 3). In contrast, there was a significant decrease ($p < 0.05$) in carotenoid content in solar dried samples during 60 days of storage. This could be attributed to the high porosity nature of solar-dried samples compared to hot air-dried samples. The porosity of dried samples facilitates oxygen transfer, hence the oxidation of carotenoids (Sablan, 2006). For example, air-dried carrots were observed to retain more carotenoids than freeze-dried carrots during storage at room temperature because freeze-dried carrots were more porous than air-dried carrots (Kaminski *et al.*, 1986). Also, storage of dehydrated products in a packaging material filled with nitrogen or vacuum could minimize the loss of carotenoids (Mini and Archana, 2016).

Total phenolic and tannin contents decreased significantly ($p < 0.05$) after 60 days of storage at room temperature. Phenolic compounds, particularly in fruits and vegetables are very unstable to storage conditions such as time and temperature. A study by Mirsaeedghazi *et al.* (2011) has found that total phenolic contents in pomegranate juice reduced (29%) when stored at -25 °C for 15 days. Besides, de Oliveira *et al.* (2017) investigated the effect of storage temperatures (4, 25, and 40 °C) and storage time on total phenolic contents, total anthocyanin contents, and tannins of sorghum during 180 days of storage. The authors concluded that the reduction in total phenolic contents, total anthocyanin contents, and tannins were greatly influenced by the storage time, with greater loss observed after 60 days of storage. When assessed for microbial safety, both hot air and solar dried cashew apple slices showed zero counts for bacterial, yeast, and mold within 60 days of storage at room temperature. This could be due to the combined effect of high sugar syrup, processing temperature (> 50 °C), and hygienic processing conditions of thorough washing of fruits, sterilization of instruments, the use of portable water, blanching of fruits, and quick packaging of fruits after drying. Though Moreno *et al.* (2013), Hasanuzzaman *et al.* (2015), and Sidhu *et al.* (2016) observed an increase in microbial load during storage in osmo-dehydrated apple, kinnow peel candy, and tomato candy respectively, the number of microbial colonies were below the maximal limit of 105 cfu/g for aerobic mesophiles and 103 cfu/g for yeast and mold. Furthermore, pathogenic bacteria such as *Staphylococcus aureus* and *Escherichia coli* were not detected in a study by Hasanuzzaman *et al.* (2015) and Sidhu *et al.* (2016). The microbial quality of food is an important criterion during processing. Factors such as moisture content, temperature, oxygen, nutrient content, and pH affect the growth of microbes in food (Jay, 2000). Osmotic dehydration and drying process reduces moisture content and increases osmotic potential in fruits, hence long shelf life during storage.

Sensory analysis of dried cashew apple slices

Organoleptic characteristics of formulated products are important quality attributes to be considered before the product is launched into the market. The scores for sensory attributes of dried cashew apple slices are summarized in Table 4. Sample B (Hot air-dried sample) exhibited significantly higher ($p < 0.05$) scores for texture. The texture of sample A (Solar dried sample) was indicated by panellists to be tough than that of B, while that of sample C (Hot air-dried sample without osmotic treatment, as a control) was very tough hence the lowest score. There was no significant difference ($p > 0.05$) of scores between samples A and B concerning colour, taste, aroma, astringent, and overall acceptability. Moreover, sample C had a significantly lower score for all sensory attributes than other products, thus the lowest preferences. This was expected as sample C had no osmotic pre-treatment, and according to Yadav and Singh, (2014), osmotic dehydration before drying improves organoleptic attributes of dried products compared to conventionally dried products.

Conclusion

This study revealed that hot air oven-dried and solar dried fruit slices had almost the same nutrient retention after processing and storage. Furthermore, products from both drying methods had similar overall acceptability and no microbial count within 60 days of storage. Sun's energy is abundant in nature, thus solar drying could be used as an alternative to hot air oven drying and other sophisticated drying methods which may be expensive and inaccessible to the low resource setting. One major drawback of solar drying though is the inability to control the environmental conditions which may sometimes lead to spoilage of samples, hence tremendous loss of food material. Therefore, the dried form of cashew apples could be regarded as a nutritious product, and that could be processed on a large scale and sold to a wide range of market segments for both income, nutrition and food security. This will ultimately reduce the post-harvest losses of cashew apples encountered at the moment.

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Conflicts of interest

The authors declare no conflict of interest.

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